On the measurement of dimensional quality of titanium alloy micro lattice struts manufactured using selective laser melting

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Abstract. The paper describes the measurement of the surface quality, dimensional accuracy, and cross sectional circularity of titanium alloy (Ti-6Al-4V) micro struts manufactured using selective laser melting. This quality is related to manufacturing and materials characteristics.

Introduction

The selective laser melting (SLM) of micro lattice structures has been an active research field at the University of Liverpool for the past few years [1,2,3,4]. Such micro lattice structures have the potential to be used as core materials in actual light weight sandwich structures [2]. However, the quality of these micro lattice structures is variable. The SLM manufacturing process is an open loop process, in which laser conditions (e.g. spot size, power and duration) are selected from an initial parametric analysis [4]. Laser conditions may not be optimal and they may degrade over time, during a build. Also, the quality of the micro lattice build is dependent on the build direction. The strut quality includes surface roughness, dimensional accuracy and cross section circularity. Fig. 1 shows micro strut details in the vicinity of a node of a BCC block [2]. The points are laser focus times, and the structure is built up from A to B to C etc. In this paper, a number of simple techniques are described to quantify and measure micro strut quality.

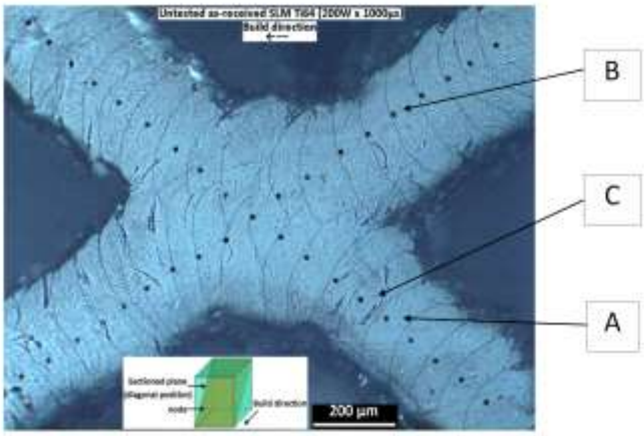
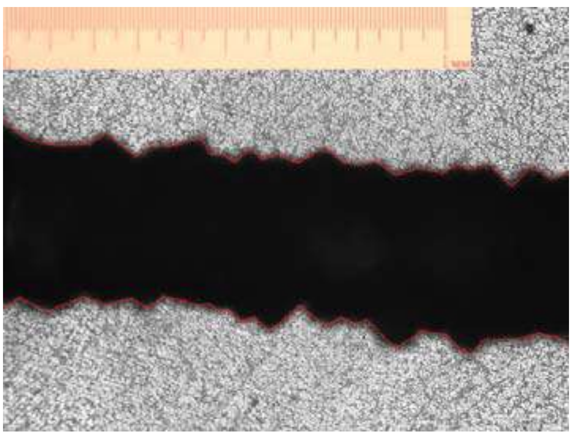
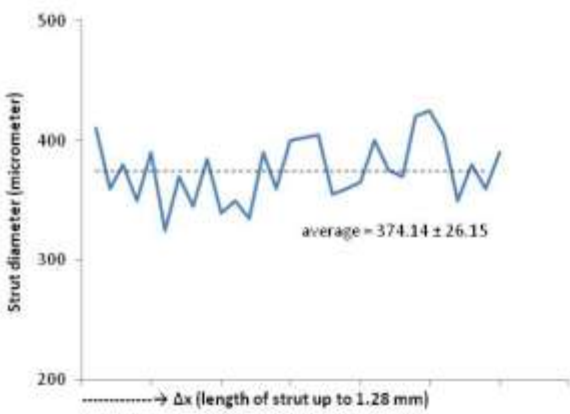


Figure 1: Detail of build quality at a node on a BCC micro lattice. Black dots are the laser focus points during build.

Surface Roughness and Dimensional Accuracy


(a)



(b)

Figure 2: (a) Shadow graph of a micro strut and (b) Quantification of variation in diameter

The micro-strut diameter was determined from shadow measurements of optical microscope images. For the shadow measurement, Kohler illumination was used. In this condition, the light was set up in a way to obtain a very uniform intensity. Fig. 2(a) shows a typical shadow graph and Fig. 2(b) gives the variation in diameter. The average micro-strut diameters that were obtained from the shadow measurement method were 374.14 ± 26.15 µm. The surface roughness profiles of the SLM Ti-6Al-4V struts in this research were also deduced from the shadow measurements. The standard surface topography components of average roughness (Ra), peak-to valley height roughness (Ry), and 10-point roughness (Rz) were measured. They were Ra = 16.8 µm Ry = 70 µm , and Rz = 59 µm, respectively. The effective stress concentration for a process-dependent surface texture was defined in terms of these parameters, and this will affect micro strut tensile strength.

Cross Section Circularity

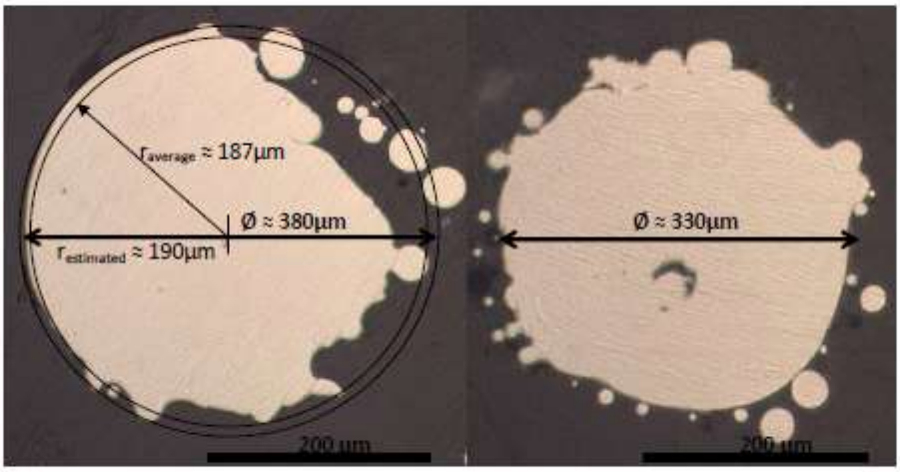


Figure 3: The nominally circular cross-sections (end parts) of the as-received SLM Ti-6Al-4V micro-strut built at 35° (Left) and 90° (Right) angles (with 200 W X 1000 µs manufacturing parameters)

The circularity of a micro strut can be represented by a circularity index (CI), using simple geometrical expressions, which has widely been used in the research of natural fibres [5]. The Circularity index of as-received SLM Ti-6Al-4V strut build at 35° was 0.824 and at 90° angle was 0.900. Besides the effect of build angle, the circularity was also affected by surface variations of struts. This was the reason for non-circularity of the theoretically fully dense solid cylindrical strut built at 90° angle. The lack of circularity will affect stress calculations and computer simulation geometry.

Discussion and Conclusions

The surface roughness, dimensional accuracy and cross sectional circularity of micro lattice struts has been quantified. These parameters need to be defined, and need to be predictable and reproducible, if SLM micro lattice structures are to be used for high performance load bearing structures. These parameters are influenced by laser conditions, scan strategies and alloy powders. For example, it has been shown that *contour* laser scan strategies provide better quality micro struts as compared to a laser *point* strategy, although the length of time for a micro strut lattice construction will increase using the *contour* approach [6].

References

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